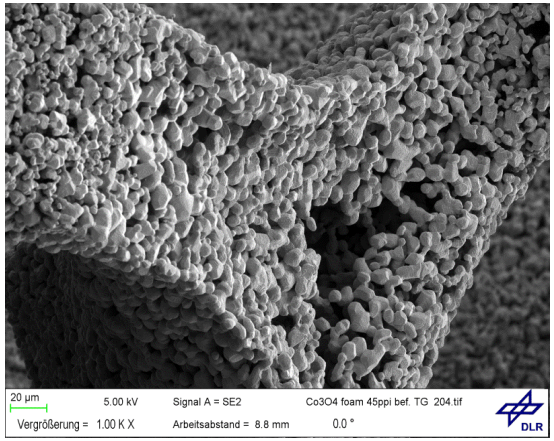
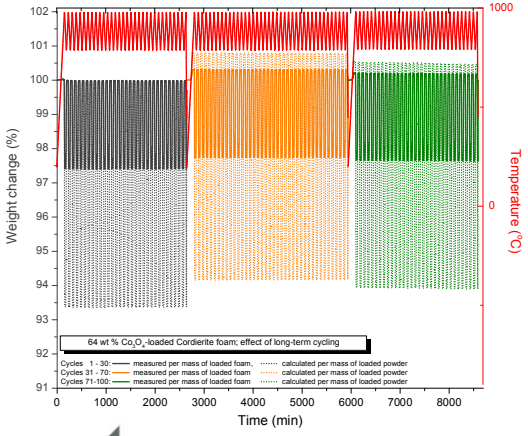
# European Efforts to Accelerate the Market Introduction of Renewable Hydrogen Production

Christian Sattler, Martin Roeb
Christian.sattler@dlr.de

# Close the Gap between Research and Application

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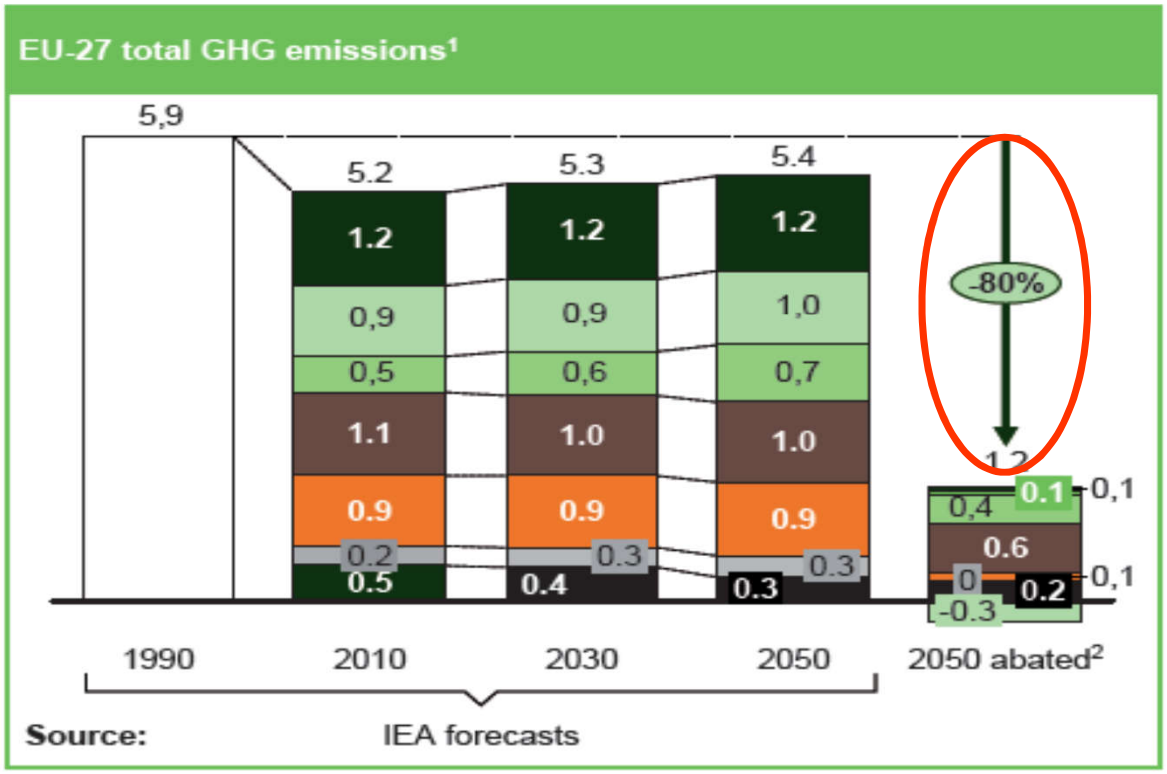
# Global change in the energy economy

- **COP 3 Kyoto 1997 – Kyoto Protocol**
- **Goal of the EU until 2050:**
  - **80%** less $CO_2$ emissions than 1990
- **Japan's hydrogen economy: 2020, 2030, 2040**
- **G7 Goals 2015, Elmau, Germany**
  - **100%** Decarbonisation until 2100
  - **100 bln $/year** for climate actions in developing countries, large share by industrial investment
- **COP 21 Paris 2015 - Paris summit**
  - Universal agreement by 195 parties (countries) to **keep a global temperature rise this century well below 2 degrees Celsius**
  - **Appropriate financial flows will be put in place,** thus making stronger action by developing countries and the most vulnerable possible, in line with their own national objectives.



# Development of EU GHG emissions [Gt $CO_2e$]




| Sector | Total abatement |
|---|---|
| Power | 95-100% |
| Road transport | 95% |
| Air & sea transport | 50% |
| Industry³ | 40% |
| Buildings | 95% |
| Waste | 100% |
| Agriculture | 20% |
| Forestry | -0.25 Gt $CO_2e$ |

1 Large efficiency improvements are already included in the baseline based on the International Energy Agency, World Energy Outlook 2009, especially for industry
2 Abatement estimates within sector based on Global GHG Cost Curve
3 CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries)

SOURCE: www.roadmap2050.eu

# Japan‘s Strategic Roadmap towards a hydrogen society

( Agency for Natural Resources and Energy, METI, 2014, revised March 2016, December 2017, October 2018)

Conveying to the world the information on the potential of hydrogen by taking advantage of the 2020 Summer Olympic Games in Tokyo

2020

2030

2040

## Phase 1

**2009: ENE-FARM DFC Program**

**2018: 270,000 DFC**

**Summer Olympic Games Tokyo**

**2020: 40,000 FCV**

**2030: 800,000 FCV**

**5,300,000 DFC**

Fuel cell vehicles: Achieving a reduction of vehicle prices to the level of hybrid vehicles of the same class and price range

## Phase 2

**Full-fledged introduction of hydrogen power generation/ Establishment of a large-scale system for supplying hydrogen**

Accelerating development and demonstration
Establishing a strategic partnership with hydrogen-suppliers overseas
Realizing inexpensive hydrogen , anticipating growth in demand

**Around 2030:**

**$H_2$ price(CIF)**

**30 JPY/Nm$^3$ = 30ct/Nm$^3$**

**= $ 3.25/kg**

from unutilized energy resources imported from overseas
- Full-fledged introduction of hydrogen power generation for power-producing business

## Phase 3

**Establishment of a zero-carbon emission hydrogen supply system throughout the manufacturing process**

Systematic development and demonstration of such a system, based on its potential for development

**Japan sets the target to procure “$CO_2$-free” hydrogen in 2040 and looks for clean and cost competitive hydrogen globally.**

DFC: Domestic Fuel Cell
FCV: Fuel Cell Vehicle
CIF : Cost, Insurance, Freight

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# Annual Hydrogen Consumption (per unit) (Source: METI, Japan)

FCV
94 kg/yr

($H_2$-type)
residential FC
201 kg/yr

FC Bus
4,600 kg/yr

**1GW $H_2$ power plant**
**(100% $H_2$ fuel)**
**200,000~400,000 ton/yr**

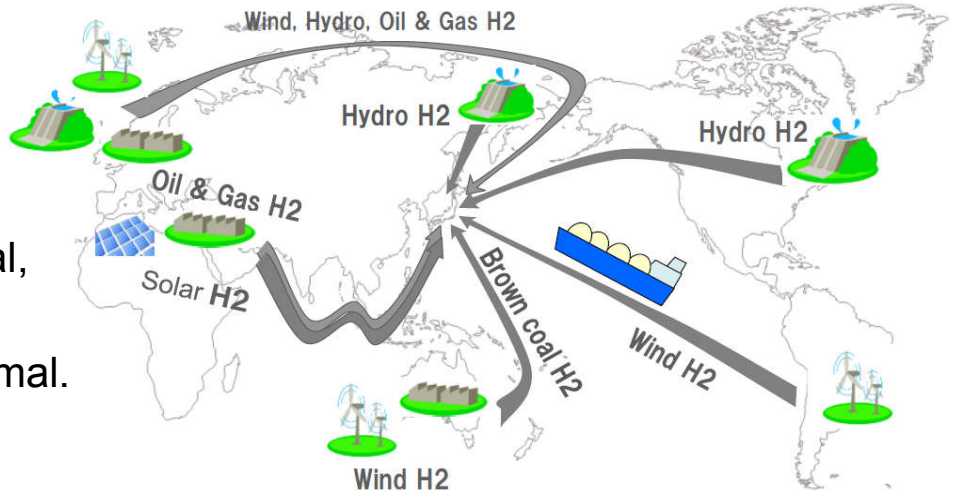
= 2~4 million FCVs

## Japanese energy mix 2013: 303 GWe,

- 44 GWe nuclear,
- 36 GWe coal,
- 41 GWe oil,
- 51 GWe autoproducers' 'combustible fuels'
- 2.6 GWe wind

45 GWe hydro,
47 GWe gas,
18 GWe oil or coal,
13 GWe solar
0.5 GWe geothermal.

(Source: IEA, 2014)




Kawasaki

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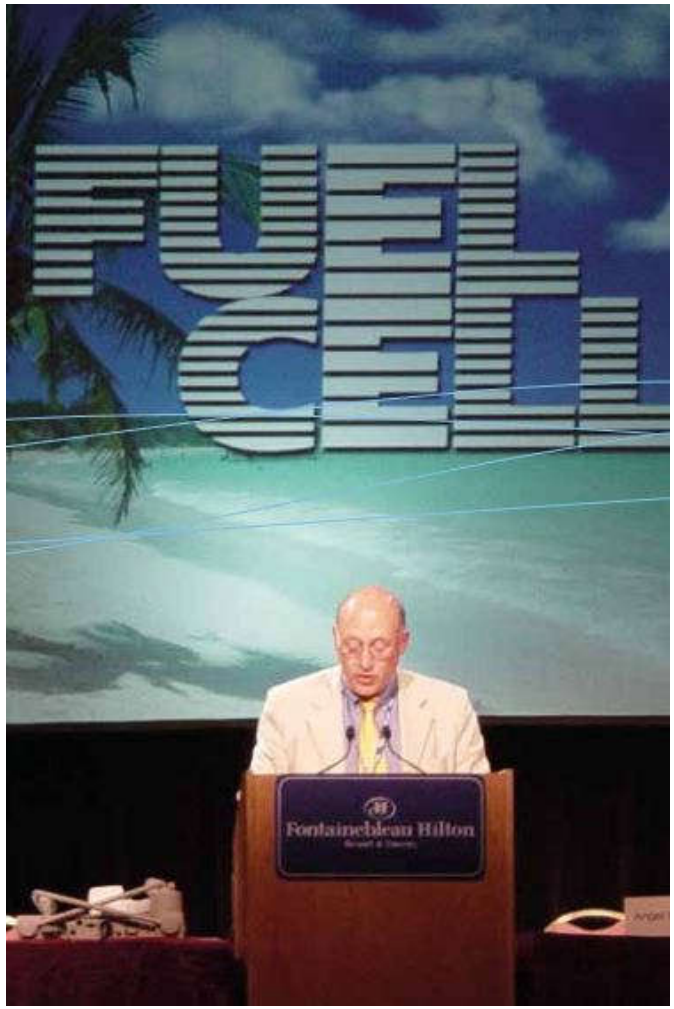
FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

- Until 2002 Hydrogen and fuel cells were topic in the EU research framework programmes
- 2002-2003 Europe developed a strategy on hydrogen and fuel cells by a **high-level groupe** of 19 leaders from industry and research with the goal of maximum impact until 2020 to achieve the goals of the SET Plan (20/20/20)




"The High-Level Group was set up to assess the feasibility of hydrogen as an energy vector for complementing electricity. Hydrogen was very promising in this regard – plus clean vehicles, clean energy
production, democratisation of energy – and a lot of beautiful things."

*Angel Perez Sainz, former Head of unit, DG Research and Innovation, European Commission*

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

- 2004-2006 Preparation of a **private public partnership** with **three partners: European Commission, Industry Grouping, and Research Grouping**. The PPP is led by industry.
- **2007-2013 FCH-JU 1**, 50:50 funded by EU and Industry+Research, budget about **740 M€** (contracts were ready in October 2008)

# FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

- 2014-2020 **FCH-JU 2**, differnt funding regulations in line with the framework programme HORIZON 2020, budget about **1250 M€**
- 2017 Industry Grouping and Research Grouping reorgnized themselves as **Hydrogen Europe and Hydrogen Europe Research – two associations, one goal, one office**

**Industry Grouping**
Hydrogen Europe

**European Union**
represented by the European Commission

**Research Grouping**
Hydrogen Europe Research

# Research is needed all along the value chain

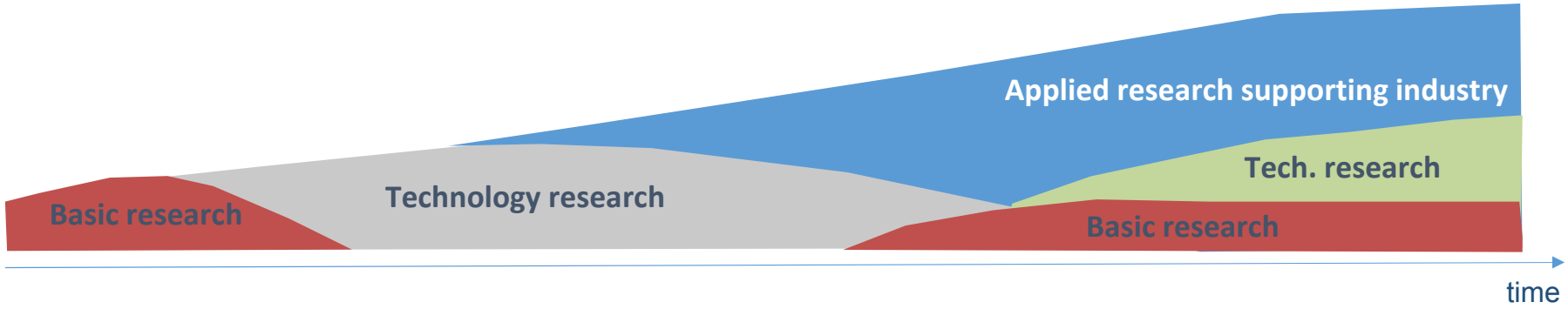
Hydrogen Europe Research

| Definition of a business case | Large scale validation | Committed deployment | Market take-off |
|---|---|---|---|

Getting core technology to the point where the “known” equipment meets the needs of viable business models and the main investments can begin.

Improving the business case.

This research work will increase as the potential profitability of the sector is demonstrated.

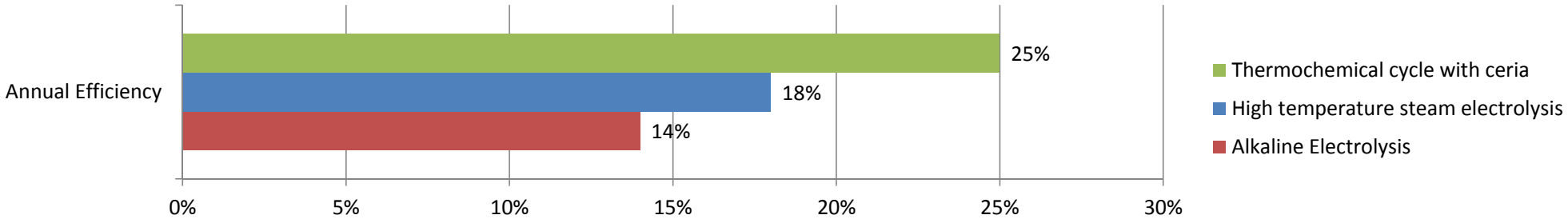



Collaboration between research and industry is key to make ideas become a reality

# Solar Hydrogen by Water Splitting: Efficiency Comparison vs. Benchmark

| Process | temperature of the chemical reaction | Solar interface receiver temperature |
|---|---|---|
| Alkaline Electrolysis | 25°C | Solar PV |
| High temperature steam electrolysis | 850°C | Future solar tower 1200°C |
| Thermochemical cycle with ceria | 1500 / 1150°C | Future solar dish 1500°C |

*G.J. Kolb, R.B. Diver SAND 2008-1900 / N. Siegel et al. I&EC Research May 2013

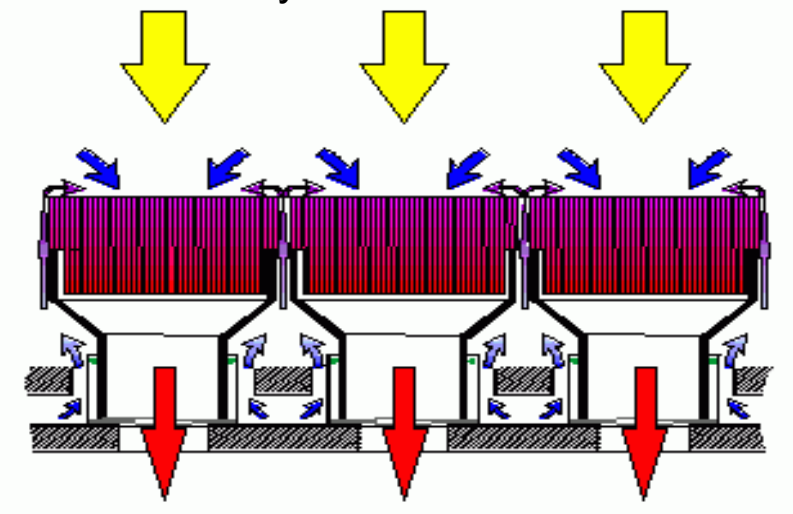


# The HYDROSOL Idea

2001, Almería, Spain – Discussion between APTL and DLR

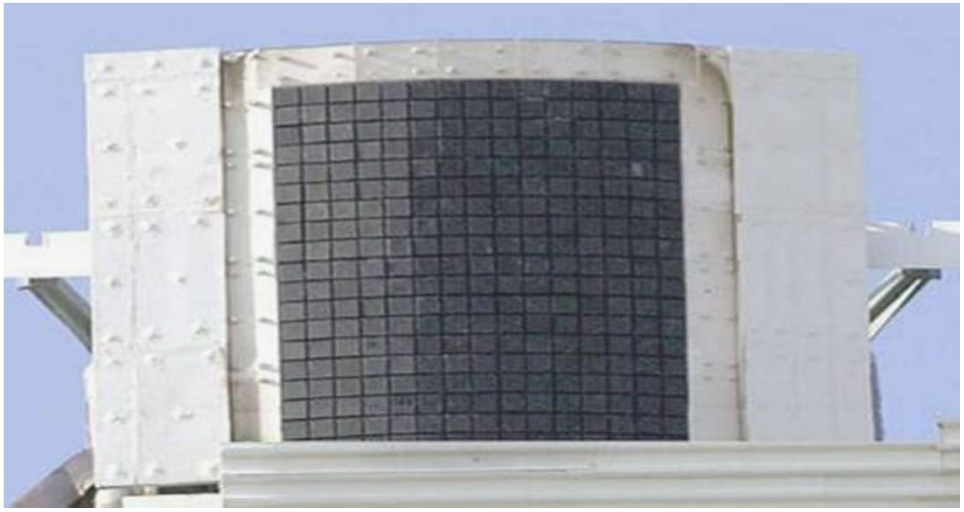
Open Volumetric Solar Receiver Design: High Temperature Air Receiver (HiTRec)

Volumetric receiver concept
SiSiC monoliths with
Honey comb structure



Hot Air 760 – 1000°C

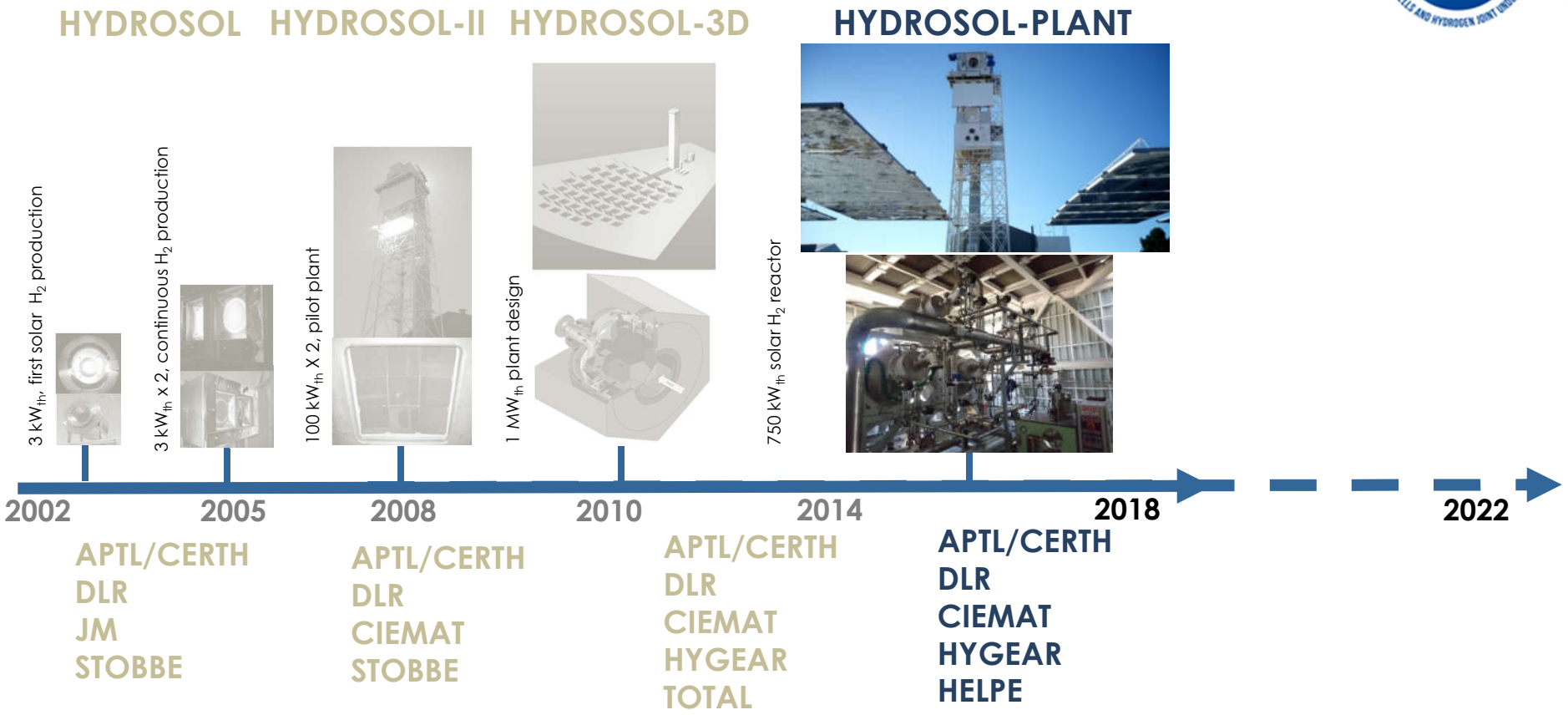
- PSA Demonstration:
  Power: 3 $MW_{th}$



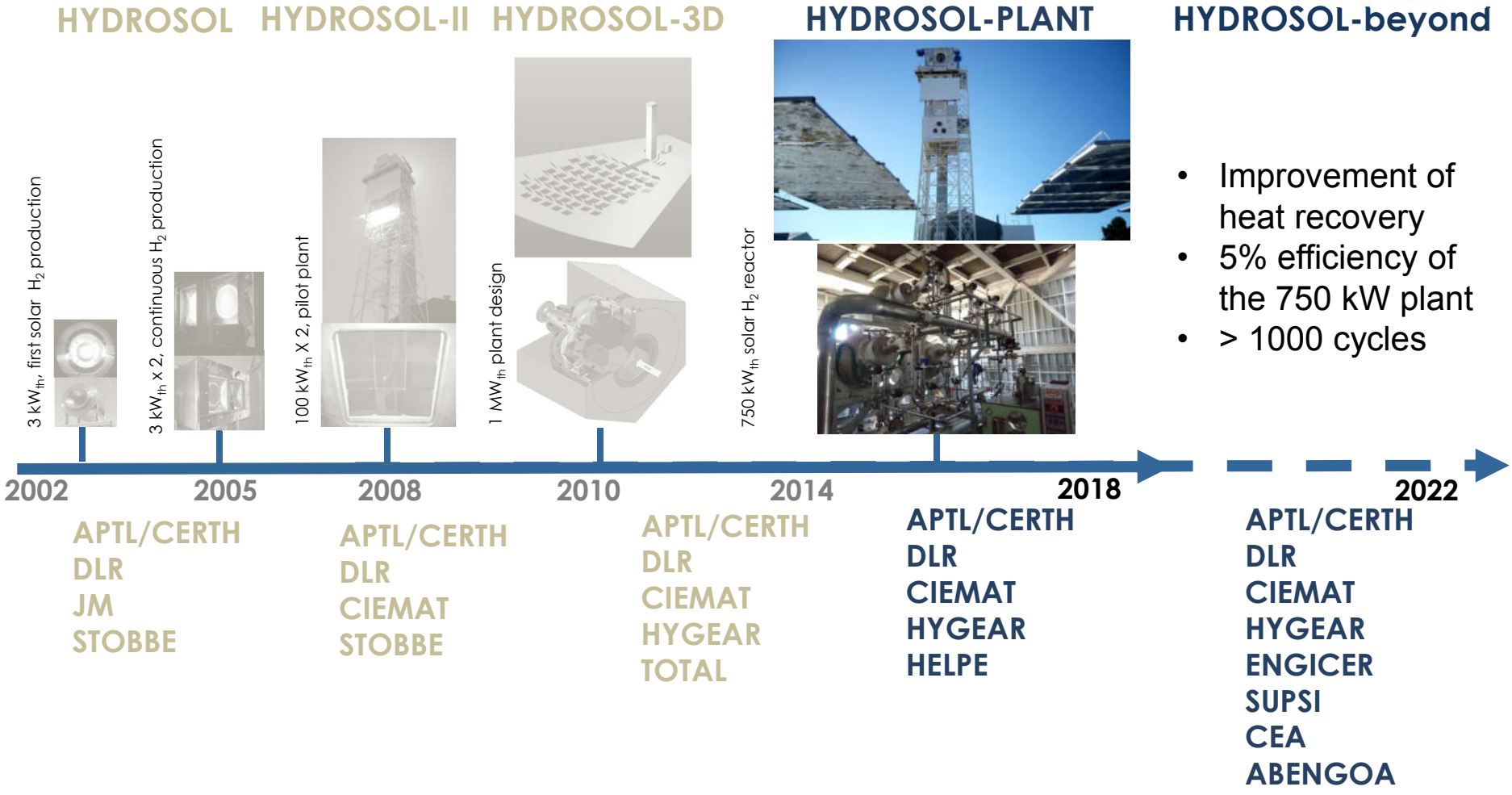
- Irradiation > 750 $kW/m^2$
- Long term test at PSA

## Result: HYDROSOL Project - STREP EU FP 5 (Nov. 2002 – Oct. 2005)

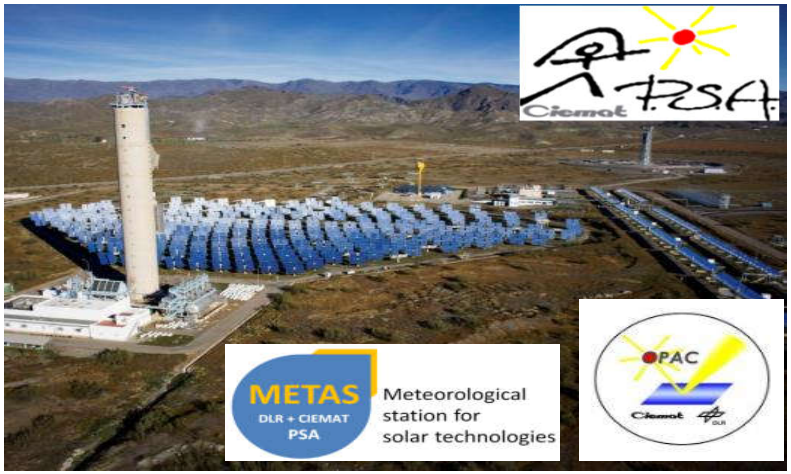
# HYDROSOL – 20 years development



# HYDROSOL – 20 years development

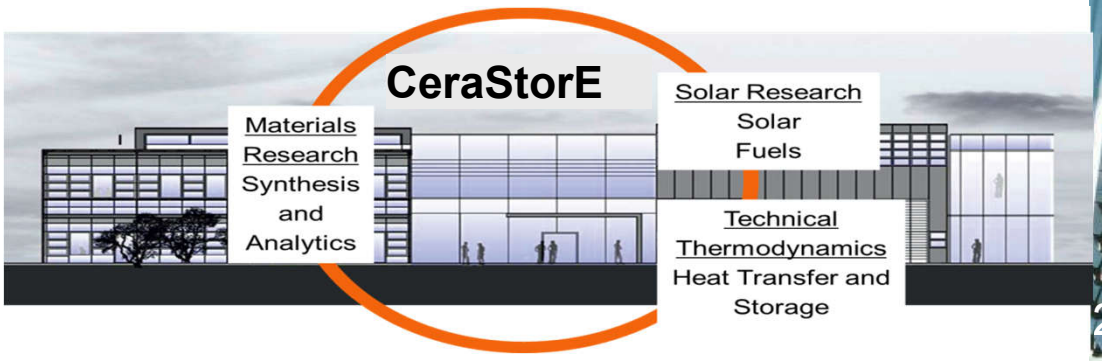


# Large scale facilities









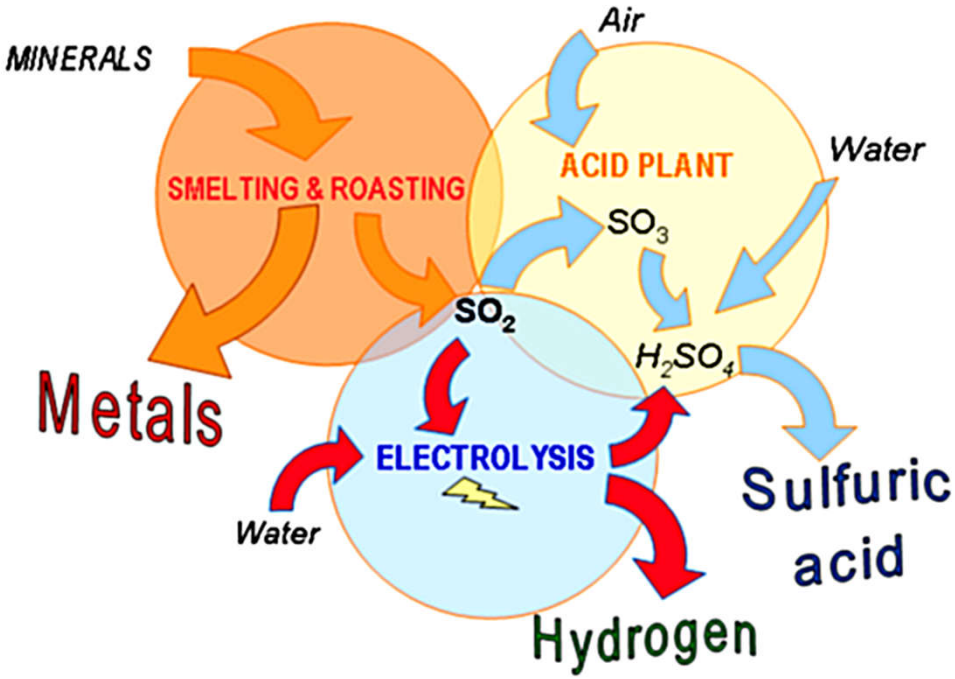


# SOL2HY2
## Solar To Hydrogen Hybrid Cycles

- FCH JU project on the solar driven Utilization of waste $SO_2$ from fossil sources for co-production of hydrogen and sulphuric acid
- Hybridization by usage of renewable energy for electrolysis
- Partners: EngineSoft (IT), Aalto University (FI), DLR (DE), ENEA (IT), Outotec (FI), Erbicol (CH), Oy Woikoski (FI)
- >100 kW demonstration plant on the solar tower in Jülich, Germany in 2015

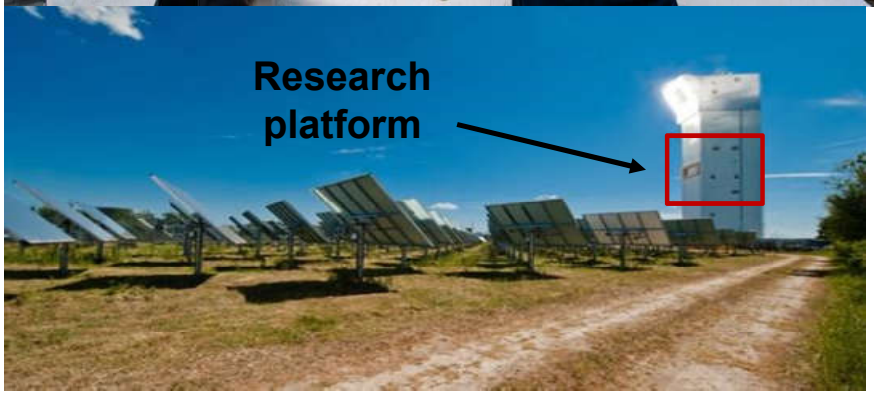
https://sol2hy2.eurocoord.com

## Outotec™ Open Cycle (OOC)




- Utilization of waste $SO_2$ from fossil sources
- Co-production of hydrogen and sulphuric acid
- Hybridization by renewable energy for electrolysis

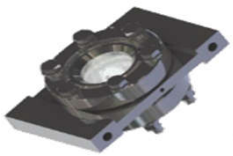
# Design of SOL2HY2 pilot plant

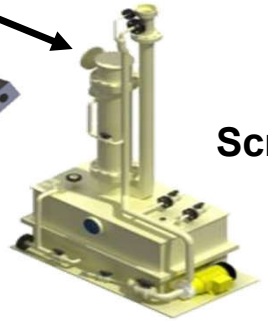





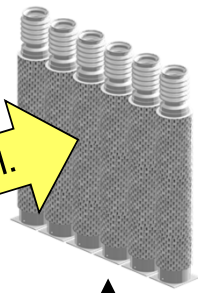
1000 °C

$SO_2$, $O_2$, $SO_3$, $H_2O$ (g)
750 °C



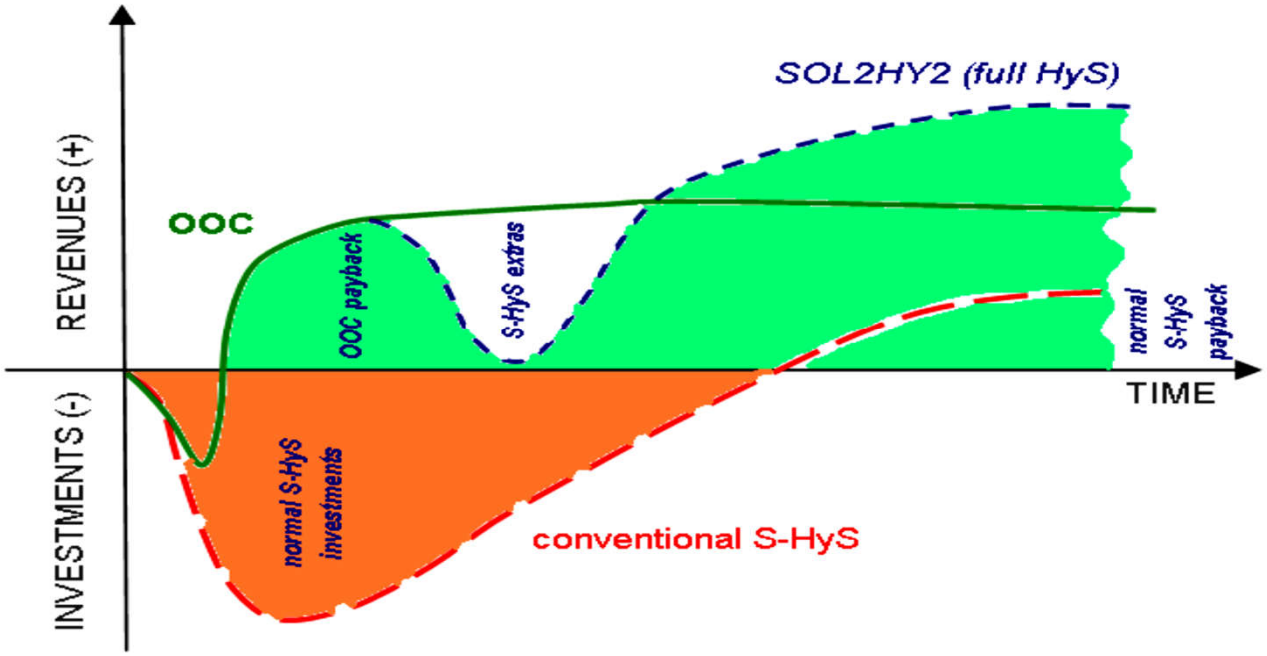




$SO_3$, $H_2O$ (g)
400 °C




$H_2SO_{4(aq)}$
1 l/min (50 w%)

# Investments vs. revenues




- Reduction of initial investments
- Financing of HyS development by payback of OOC
- Increase of total revenues

# Centrifugal particle solar receiver optimization

## Application of pilot receiver developed in CentRec project

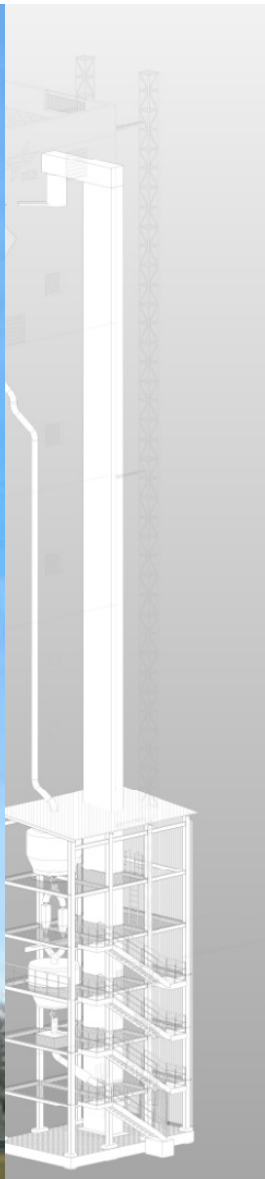
- Centrifugal particle receiver was erected on scaffold in front of Juelich Solar Tower
  - Nominal power: **2.5 $MW_{th}$**
  - Diameter of the aperture: 1.13 m
  - Max. particle temperature: 1000 °C

**Project PEGASUS**

- Solar testing of particles in CentRec pilot was carried out in 2018
- Pre-testing of catalytic particles is underway (i.e. absorptance, pouring angle, flow angle, thermo-shock, crushing resistance, abrasiveness, emissivity)
- **3 tons of catalytic particles** will be produced, and tested probably in 2021
  - The reason is that DLR just builds a second tower next to the existing one as the facility is completely booked for years

# Multi-focus-Tower (MFT)

- Multi-focus-Tower next to STJ
  - Uses the same heliostat field
  - Concentration 1000 kW/m²
  - Three levels, 2 m² receiver-apertur
  - Platform for particle receiver and storage tests
  - Large heat-storage demonstration
- Construction already started
  - Inauguration in 2020
  - Start of operation 2020-2021



# MISSION INNOVATION

- Is a global initiative of **23 countries and the European Commission (for the EU)**
  - reinvigorate and accelerate global clean energy innovation
  - make clean energy widely affordable
- MI was announced at COP21
- Seek to **double governmental and/or state-directed clean energy research, development and demonstration (RD&D) investments over five years**
- **Work closely with the private sector** as it increases its investment in the earlier-stage clean energy companies that emerge from government programs
- Web-site: http://www.mission-innovation.net


**Fourth Mission Innovation Ministerial** gathering (MI-4), will take place in Vancouver, Canada on May 28th, 2019.

MISSION INNOVATION

# Innovation Challenge 5: Converting Sunlight

**Objective IC5:** To discover affordable ways to convert sunlight into storable solar fuels.

**Co-leads:** European Commission, Germany

**Participants:** Australia, Brazil, Canada, Chile, China, Denmark, Finland, France, India, Italy, Japan, Mexico, Netherlands, Norway, Saudi Arabia, Sweden, UAE, UK, **USA**

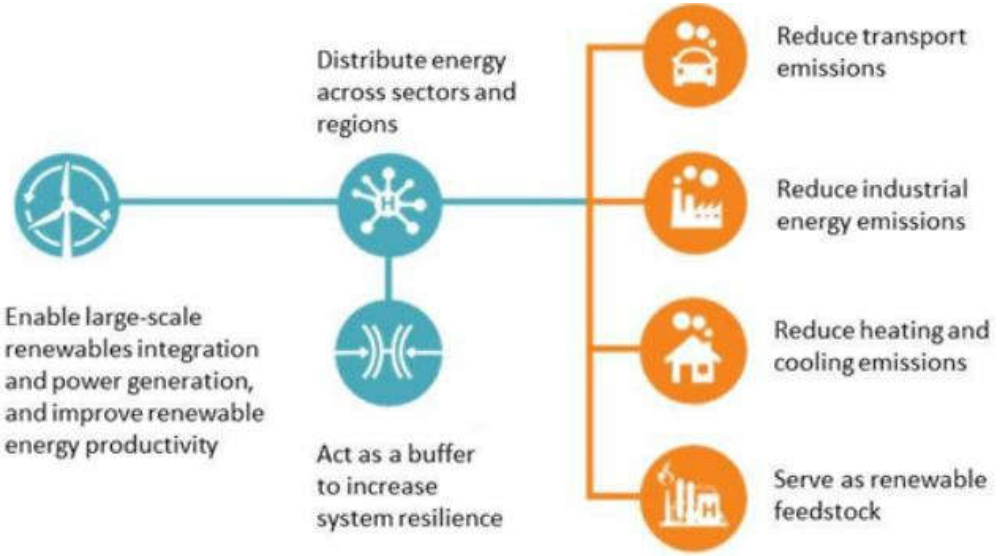
MISSION INNOVATION

# Innovation Challenge 8: Renewable and Clean Hydrogen

**Objectives IC8:** To accelerate the development of a global hydrogen market by identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale.

**Co-leads:** Australia, European Commission, Germany

**Participants:** Austria, Canada, Chile, China, France, India, Italy, Japan, Netherlands, Norway, Saudi Arabia, UK, **USA**



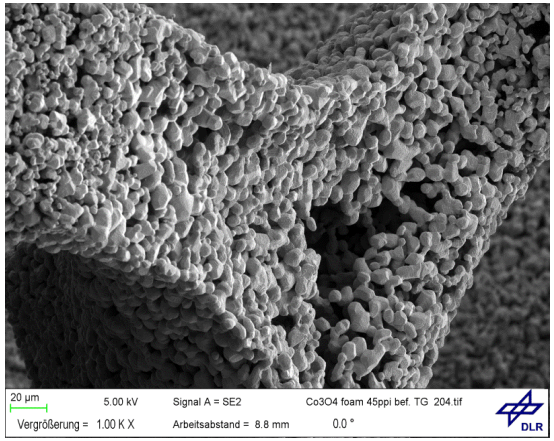
# $H_2$ Mobility

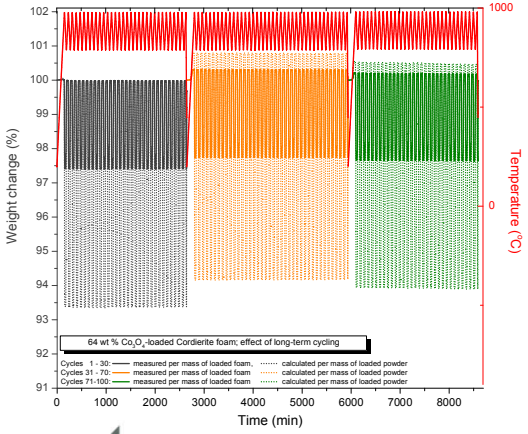
- Started in Germany with six companies: **Air Liquide, Daimler, OMV, Shell, Linde, Total** and five associated partners: **BMW, Honda, Hyundai, Toyota, Volkswagen**
- Common goal: To put in place the infrastructure to guarantee nationwide hydrogen-powered mobility in Germany
- Extended to Europe

| Country | Installed | In Preparation |
|---|---|---|
| Iceland | 1 | |
| Norway | 5 | |
| Sweden | 3 | |
| Estonia | | 1 |
| Latvia | | 1 |
| Denmark | 9 | 1 |
| UK | 13 | 2 |
| The Netherlands | 2 | 4 |
| Belgium | 2 | |
| Germany | 66 | 34 |
| France | 5 | 2 |
| Czech Republic | | 3 |
| Switzerland | 1 | |
| Austria | 5 | |
| Spain | | 2 |
| Italy | 1 | |
| | **113** | **50** |


https://h2.live Status April 22

# Close the Gap between Research and Application




Team up!

H2 MOBILITY FUELLING HYDROGEN

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Hydrogen Europe Research

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# Thank you very much for your attention!